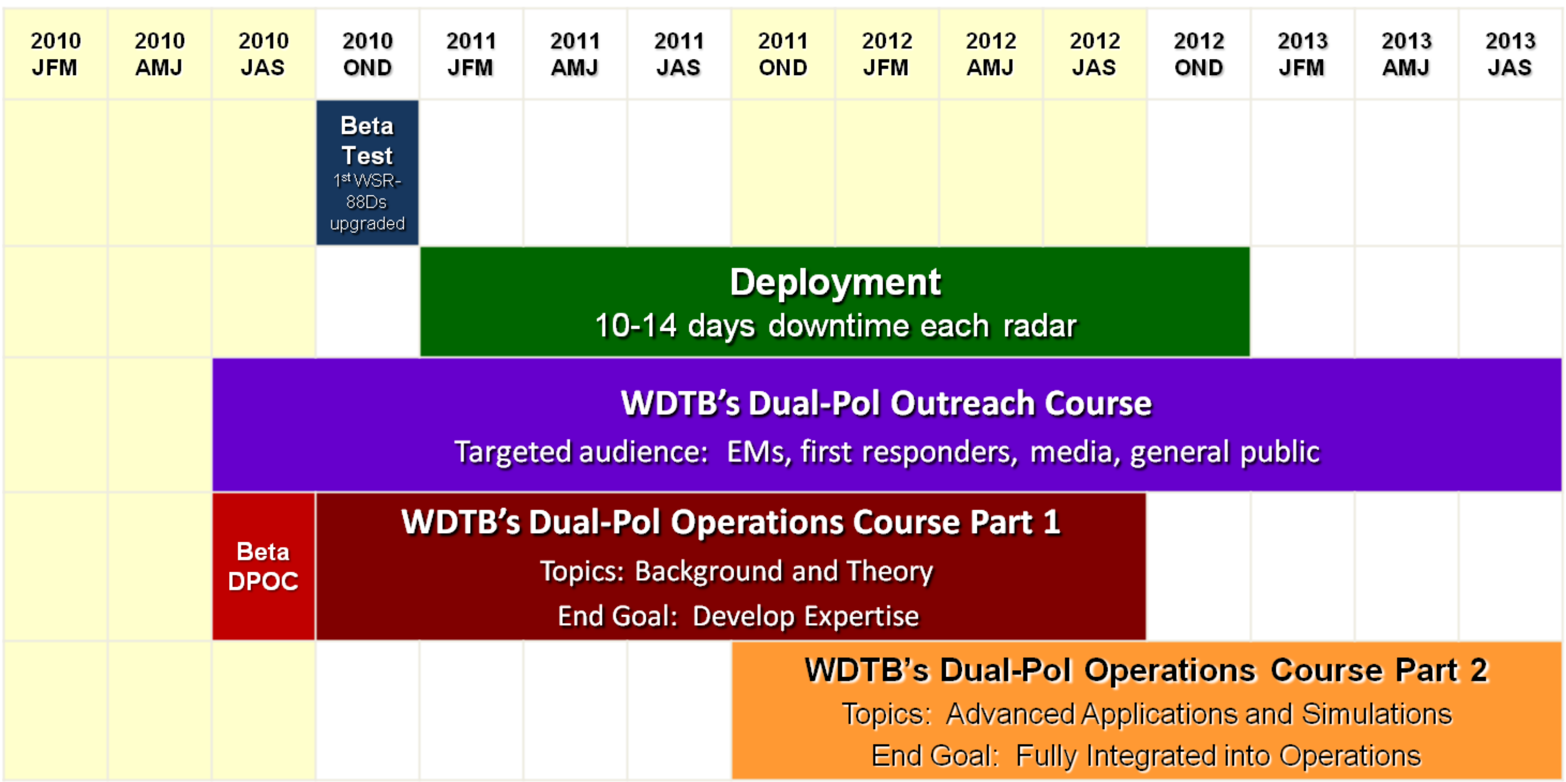
POLARIMETRIC RADAR IMPROVEMENTS

DUAL-POLARIZATION OF WSR-88D NETWORK

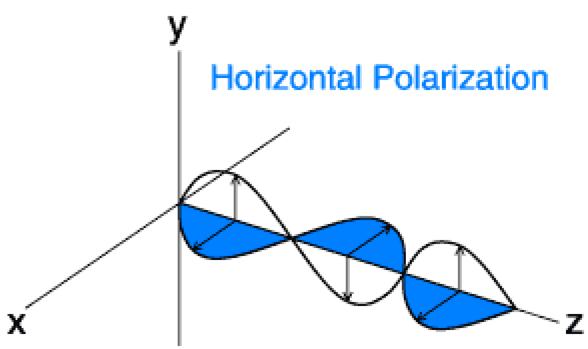
Dual-Pol: Coming to KLOT!

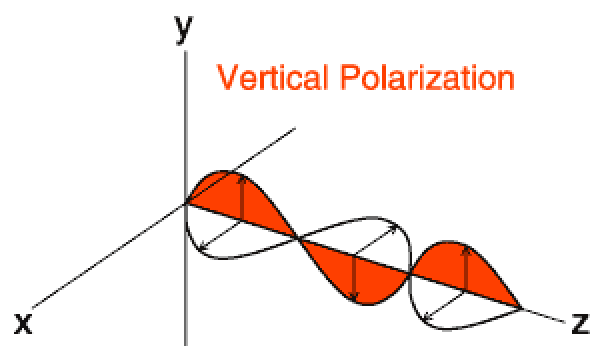
- KLOT will be part of the Dual Threaded Beta Test beginning in March 2011



What is Dual-Polarization?

- A radio wave is a series of oscillating electromagnetic fields. If we could see them, they would look like this:



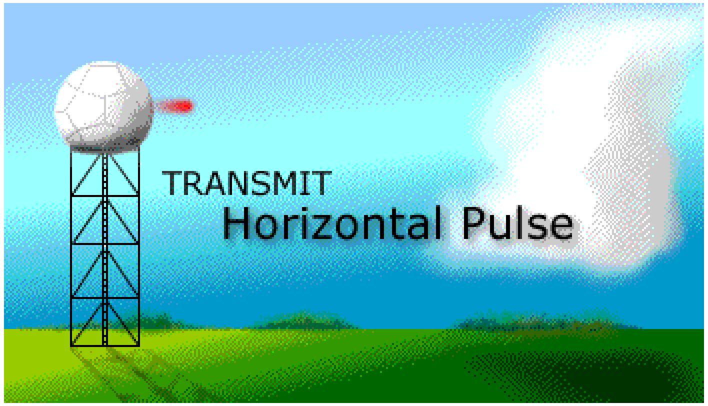


What is Dual-Polarization?

- Most radars (WSR-88D included) transmit and receive radio waves with a single, horizontal polarization
- Polarimetric radars transmit and receive both horizontal *and* vertical polarizations
- This is most commonly done by alternating between horizontal and vertical polarizations with each successive pulse

Polarimetric Radar:

- Polarimetric radars measure both the horizontal and vertical dimensions of cloud and precipitation particles.



Why are two poles better than one?

- By comparing these reflected power returns of the two phases in different ways (ratios, correlations, etc.), we are able to obtain information on the size, shape, and ice density of cloud and precipitation particles.

Benefits of Dual-Polarization:

- Improved accuracy of precipitation estimation!
- Hydrometeor identification (rain vs. hail)
- Droplet distributions (rainfall rates)
- Identification of frozen/freezing vs. liquid hydrometeors
- Differentiation of non-meteorological targets

What does a polarimetric radar measure?

- (V): mean radial velocity
- (SW): spectrum width
- (Z): reflectivity factor for horizontal polarization
- (ZDR): Differential Reflectivity
- (CC): correlation coefficient
- (KDP): specific differential phase

Let's Look Closer:

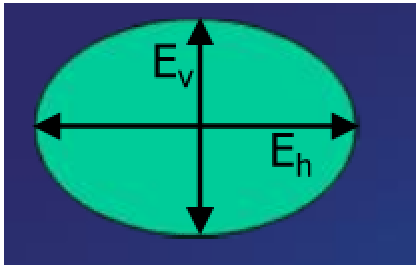
- Differential Reflectivity
- Correlation Coefficient
- Specific Phase Differential

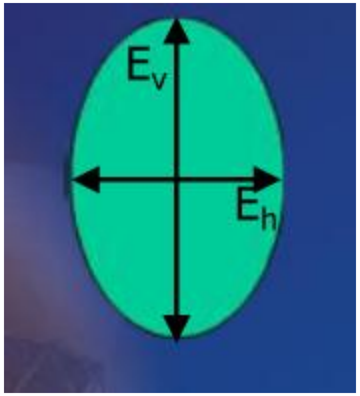
Differential Reflectivity (ZDR)

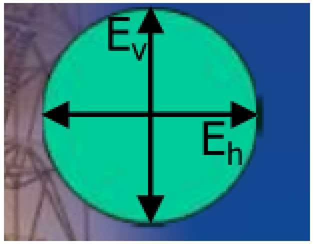
- Ratio of reflected horizontal and vertical power returns
- Depends on the median shape and size of scatterers in a *Radar Cross Sectional Area*
- Amongst other things, it is a good indicator of drop shape. In turn, the shape is a good estimate of average drop size.

Differential Reflectivity (ZDR):

- ZDR > 0: positive ZDR means horizontally oriented mean profile
- ZDR < 0: negative ZDR indicates vertically oriented mean profile
- ZDR ~ 0: Spherical mean profile





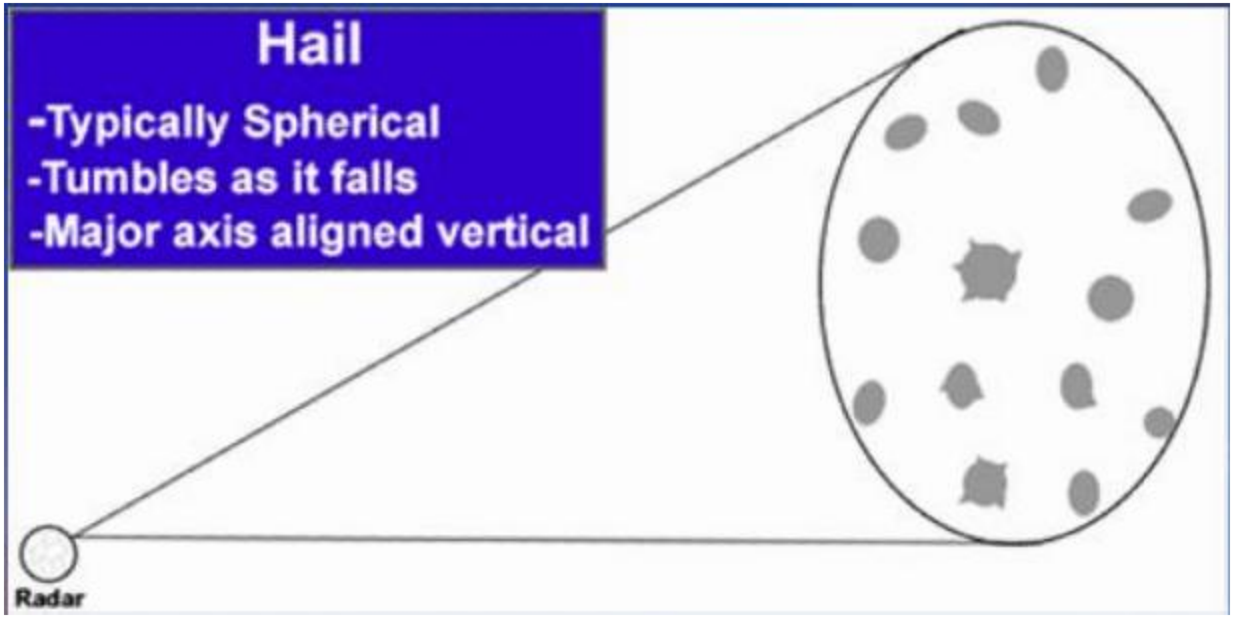


ZDR > 0:

- Positive ZDR indicates a mean power return profile wider than it is tall
- Larger positive ZDR usually indicates the presence of larger liquid drops
- Falling rain drops flatten into “hamburger bun” shape (generally range from 0.5 to 5.0 dB)

ZDR ~ 0:

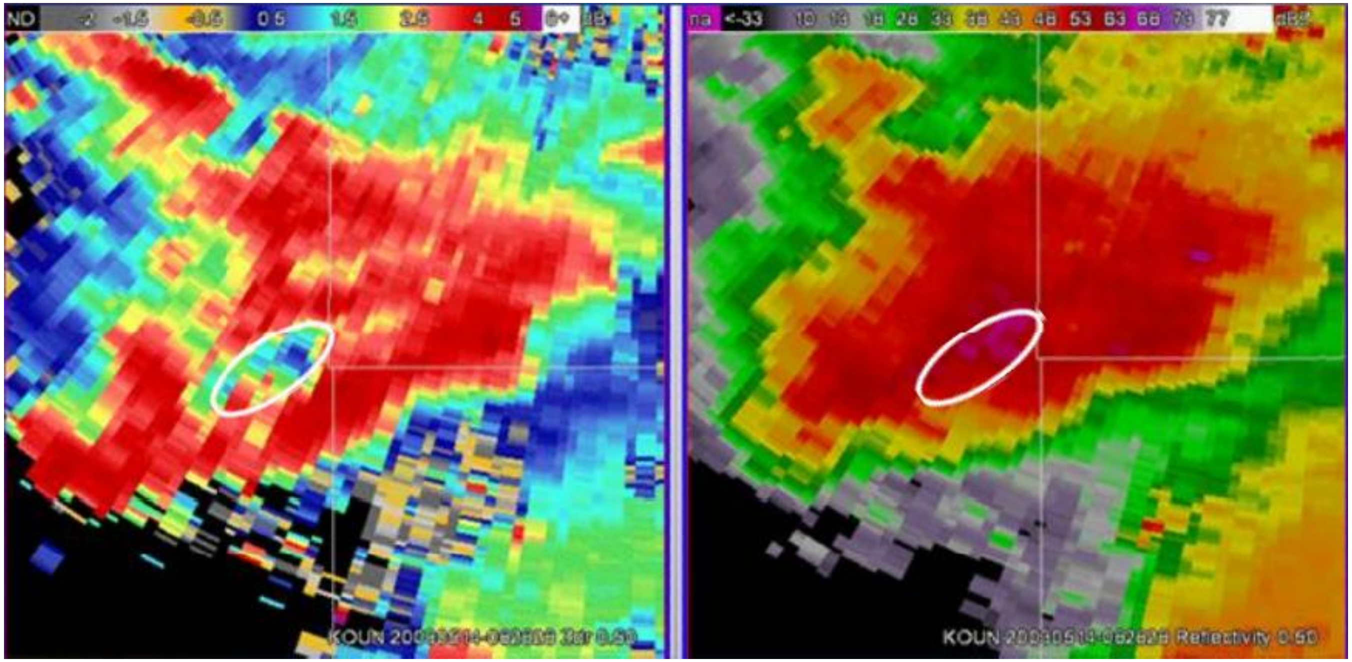
- ZDR values around zero indicate a spherical mean profile power return
- tumbling hail stones result in nearly spherical return



Hail Core Example:

Z on right:
note high reflectivity core in purple

ZDR on left:
note minima of near zero where highest Z co-located. This indicates hail core!

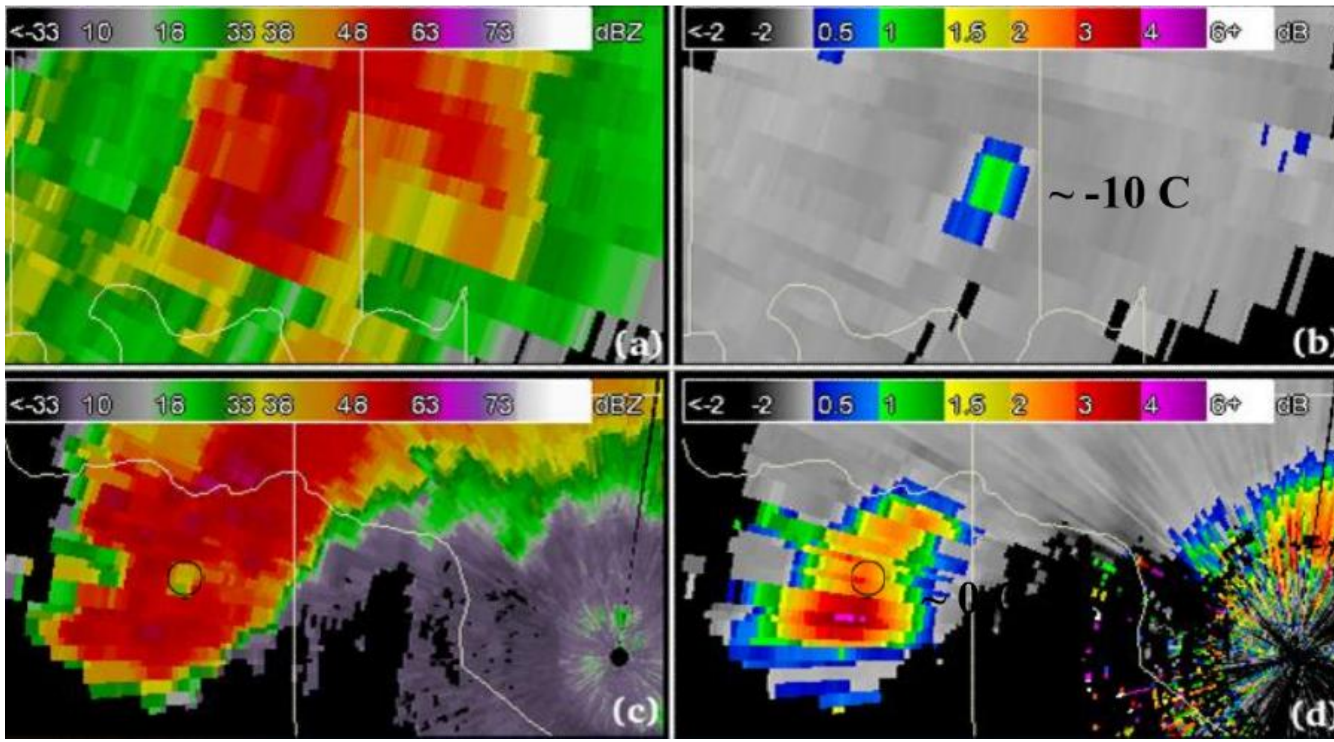


Updraft Location Example:

Z left, ZDR right: Note positive values of ZDR well above freezing level.

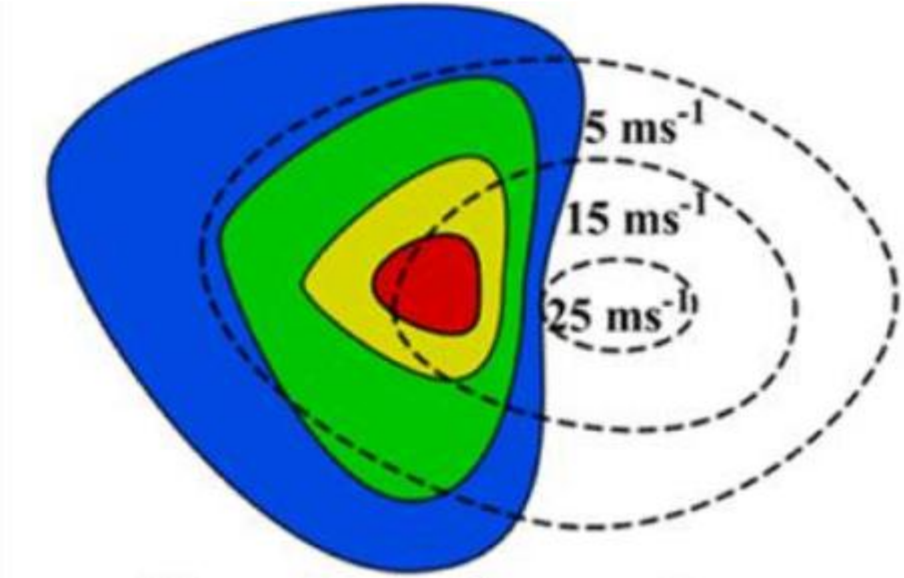
This indicates liquid drops held aloft in updraft.

Note large positive ZDR in BWER.



Updraft Location Example:

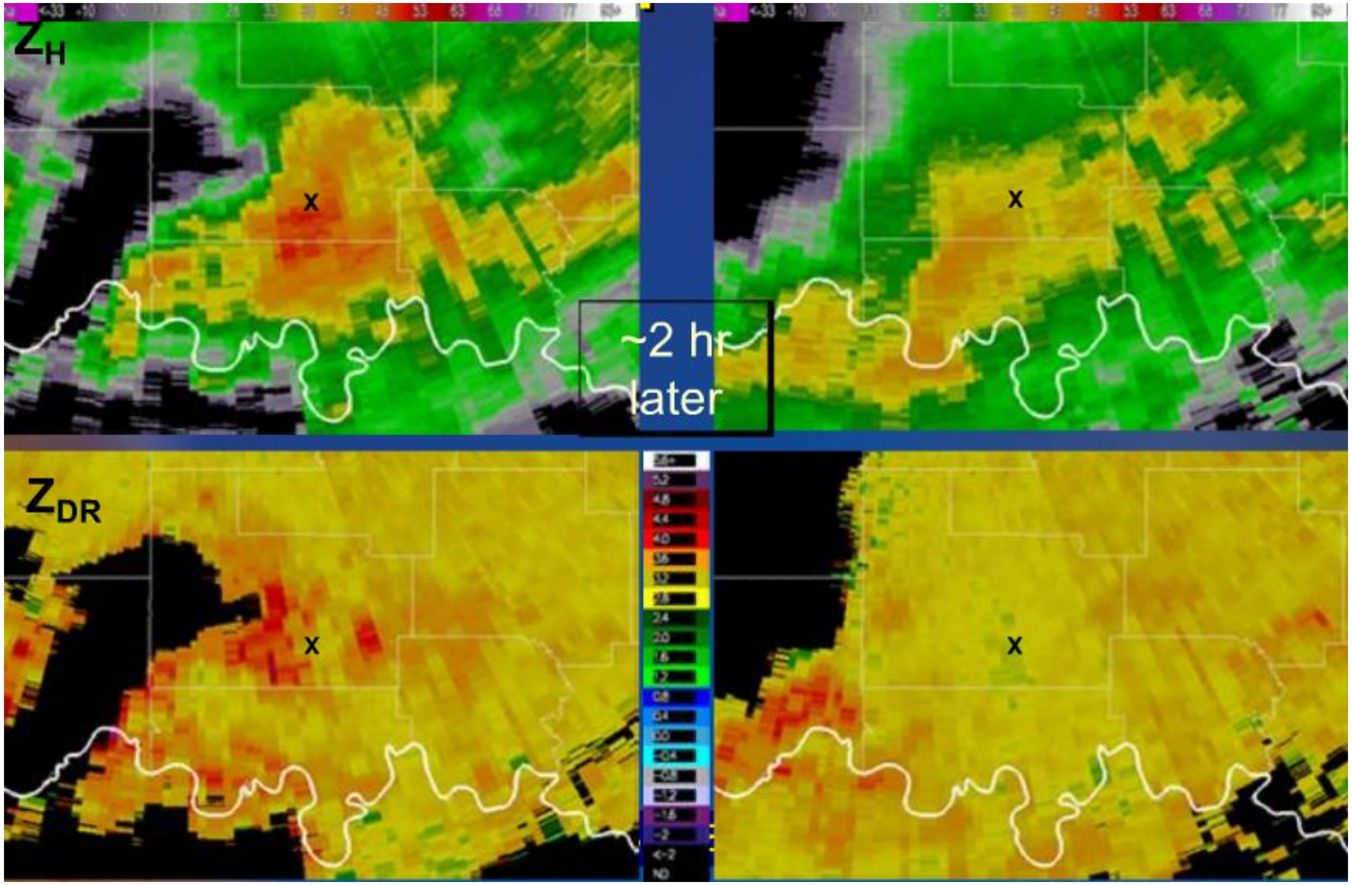
Greatest ZDR usually displaced upwind of actual updraft column



Rain/Sleet Changing to Snow:

Left: High ZDR indicates liquid covered sleet/snow

Right: 2 hours later, precip changing to snow. Note decrease in ZDR



ZDR Summary & Limitations:

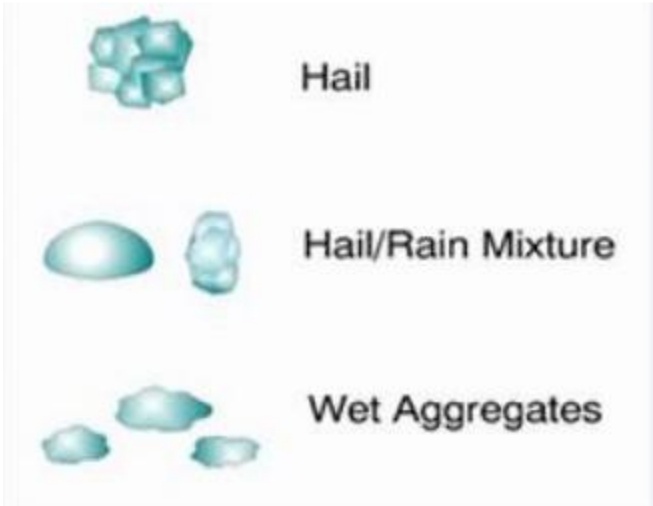
- Not immune to data quality issues
- +ZDR: greater than 1-2 mm liquid drops
- ++ZDR: large liquid drops, perhaps with ice cores
- 0 ZDR: spherical or effectively spherical, most likely hail if coincident with higher Z
- Used to identify hail shafts, convective updrafts, regions of liquid vs. frozen hydrometeors

Correlation Coefficient (CC):

- Correlation between the horizontal and vertical backscattered power from the scatterers within a sample volume (zero to 1)
- Think “Spectrum Width” for hydrometeors
- Large spread of hydrometeor sizes and shapes results in lower correlation

Correlation Coefficient:

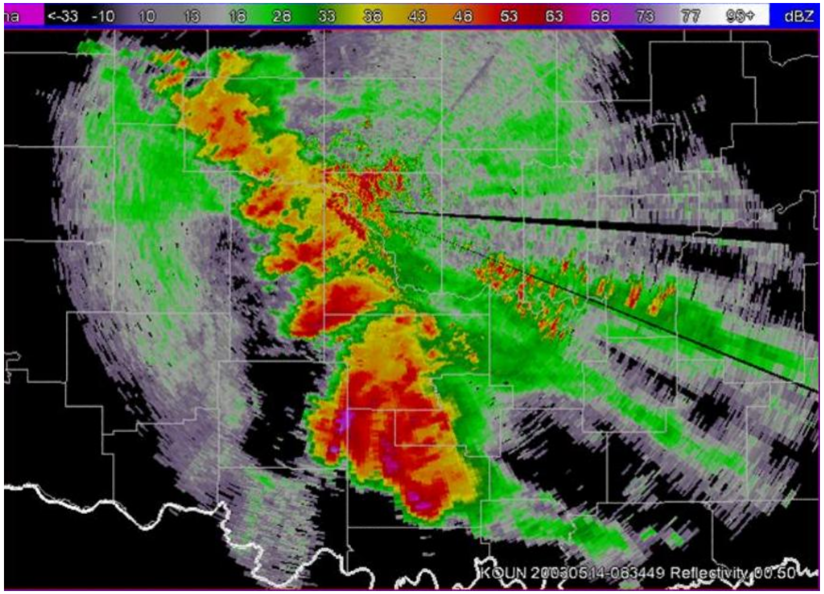
- 0.96<CC<1 – Small hydrometeor diversity*
- 0.85 <CC<0.96 – Large hydrometeor diversity*
- CC < 0.85 – Non-hydrometeors present
- * refers to sizes, shapes, orientations, etc.



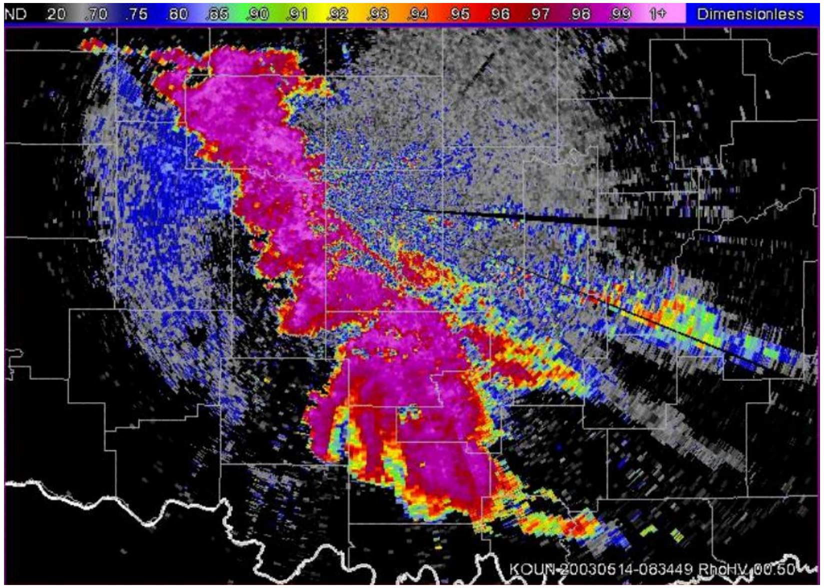
CC: What is it good for?

Absolutely Something! Say it Again!

Reflectivity:



Correlation Coefficient:

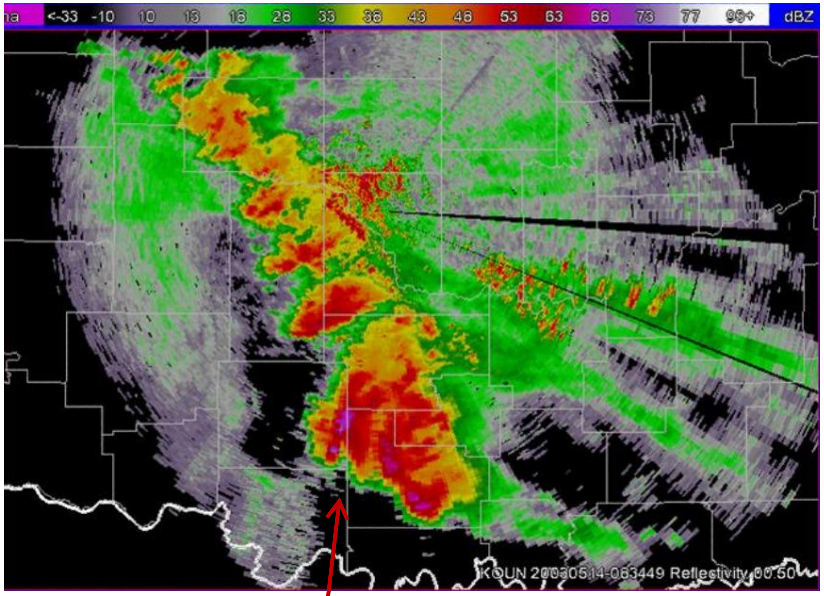


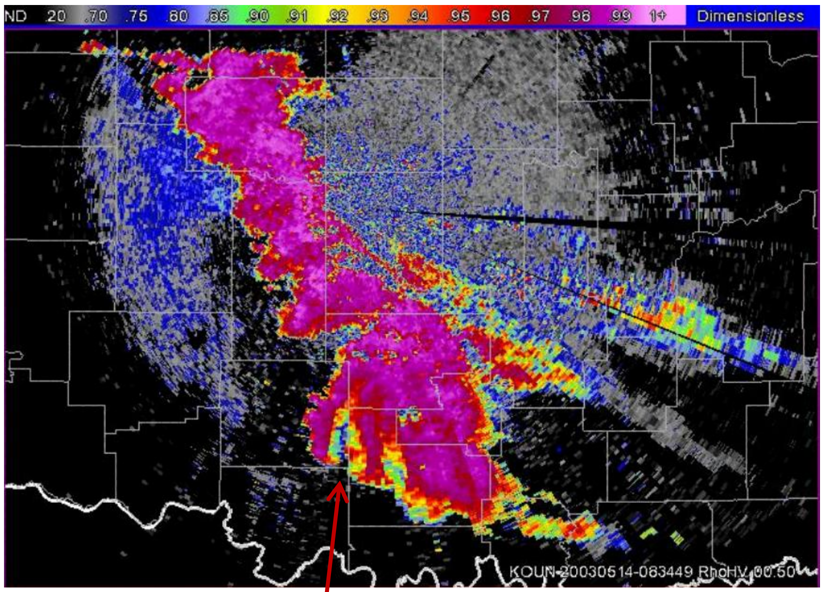
Note area on left of each image: Low CC identifies this as non-meteorological returns.

Very Large Hail and Correlation:

Note high Z (purple)

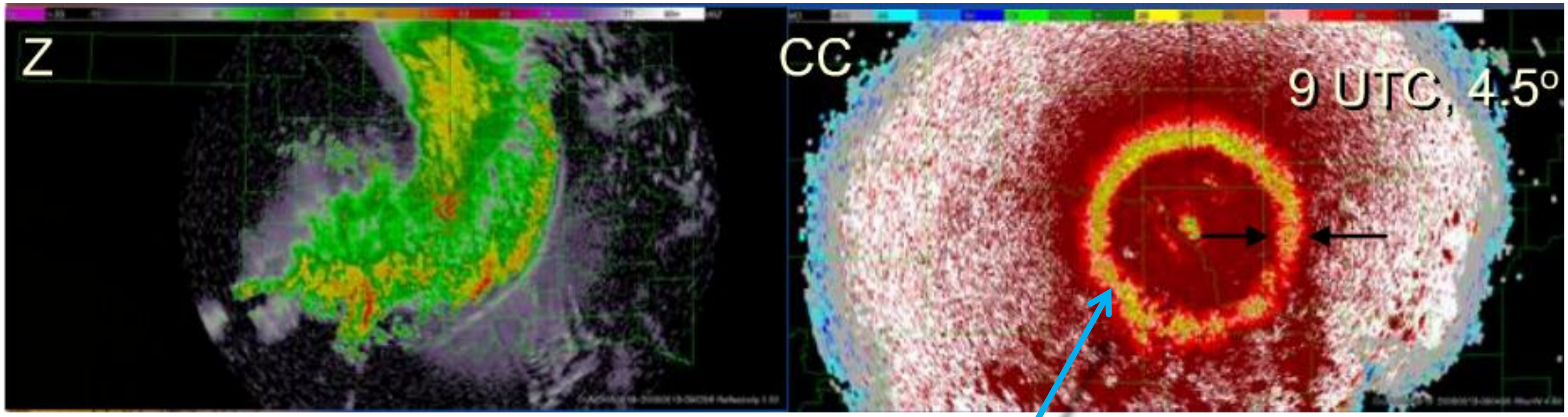
But low CC





CC only valid for Rayleigh scattering, not Mie scattering.

Melting Layer Example:

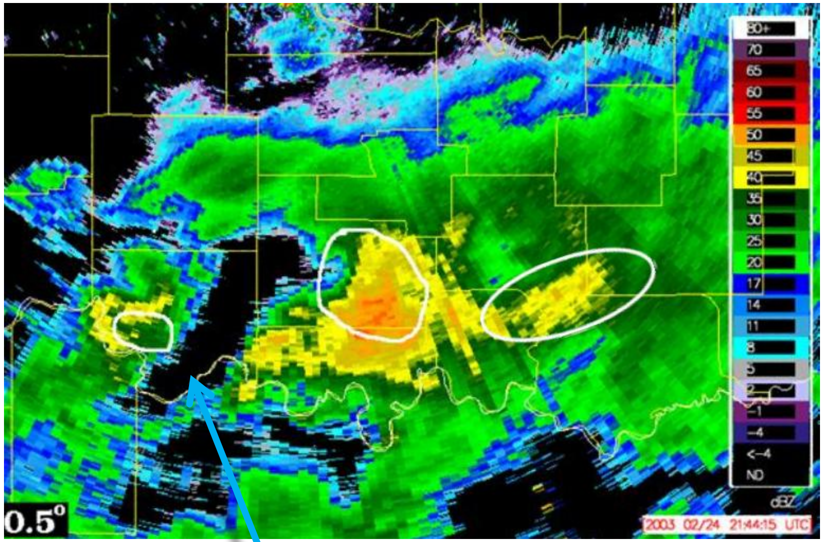


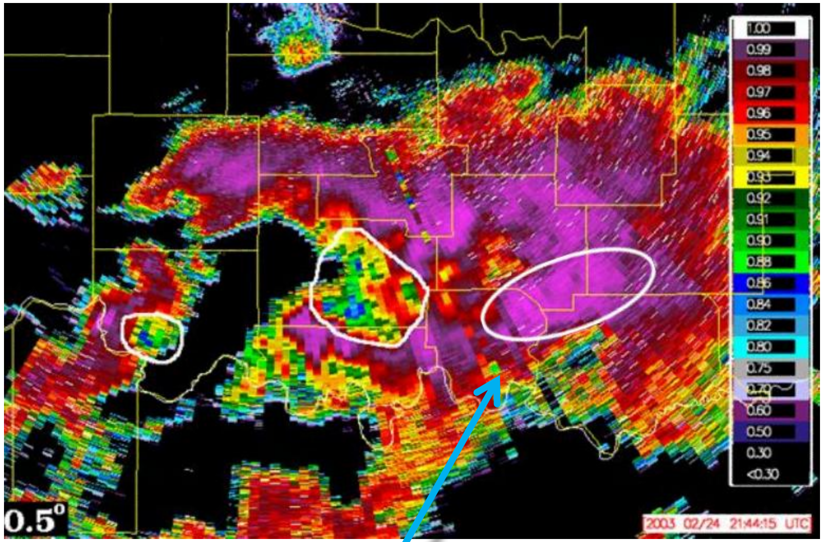
Note low CC where mixed phase precipitation occurring in melting layer

CC in Winter Precipitation:

Reflectivity:

Correlation Coefficient:





High CC indicates all one precip type.
Low CC indicates mix (melting)

CC Summary and Limitations

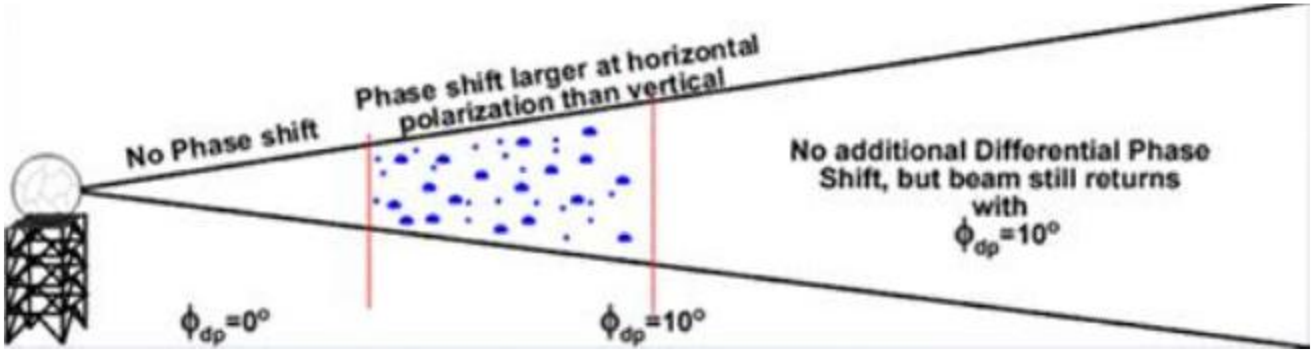
- Affected by SNR
- Same limitations as with any backscattering variable
- Values > 0.95 indicate consistent size, shape, orientation, and/or phase of hydrometeors
- Values < 0.95 indicate a mixture of size, shape, orientation, and/or phase of hydrometeors
- Very low (0.80 or less) means very large hail, or non-meteorological scatterers

Specific Differential Phase: (KDP)

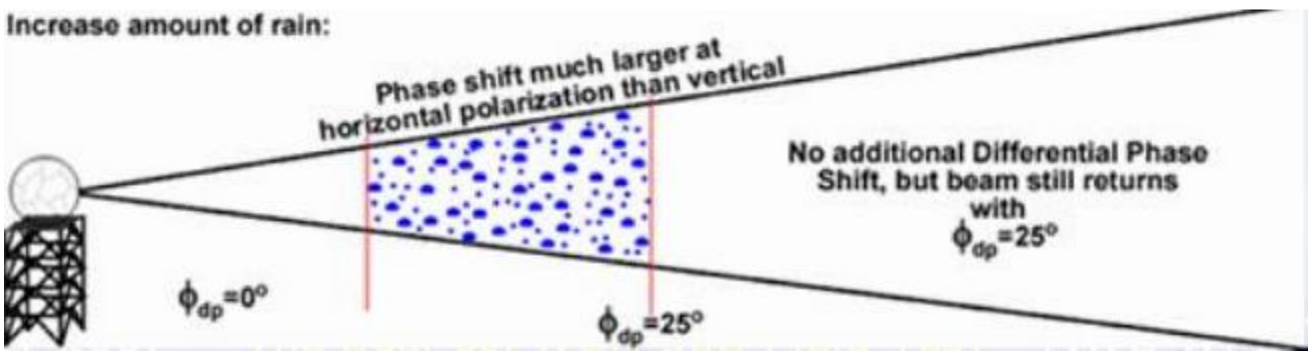
- Differential phase shift between horizontal and vertical returned energy
- Greater numbers of hydrometeors result in greater phase differential (actually in gradient of phase change along radial)
- This allows algorithms to estimate rainfall rates and amounts
- Zero and negative ZDR can be ignored, as it is most likely hail or non-meteorological
- This allows for precipitation estimation that ignores hail and ground clutter!

End Result Should Be Much Improved Precipitation Estimation!

Phase Shift:

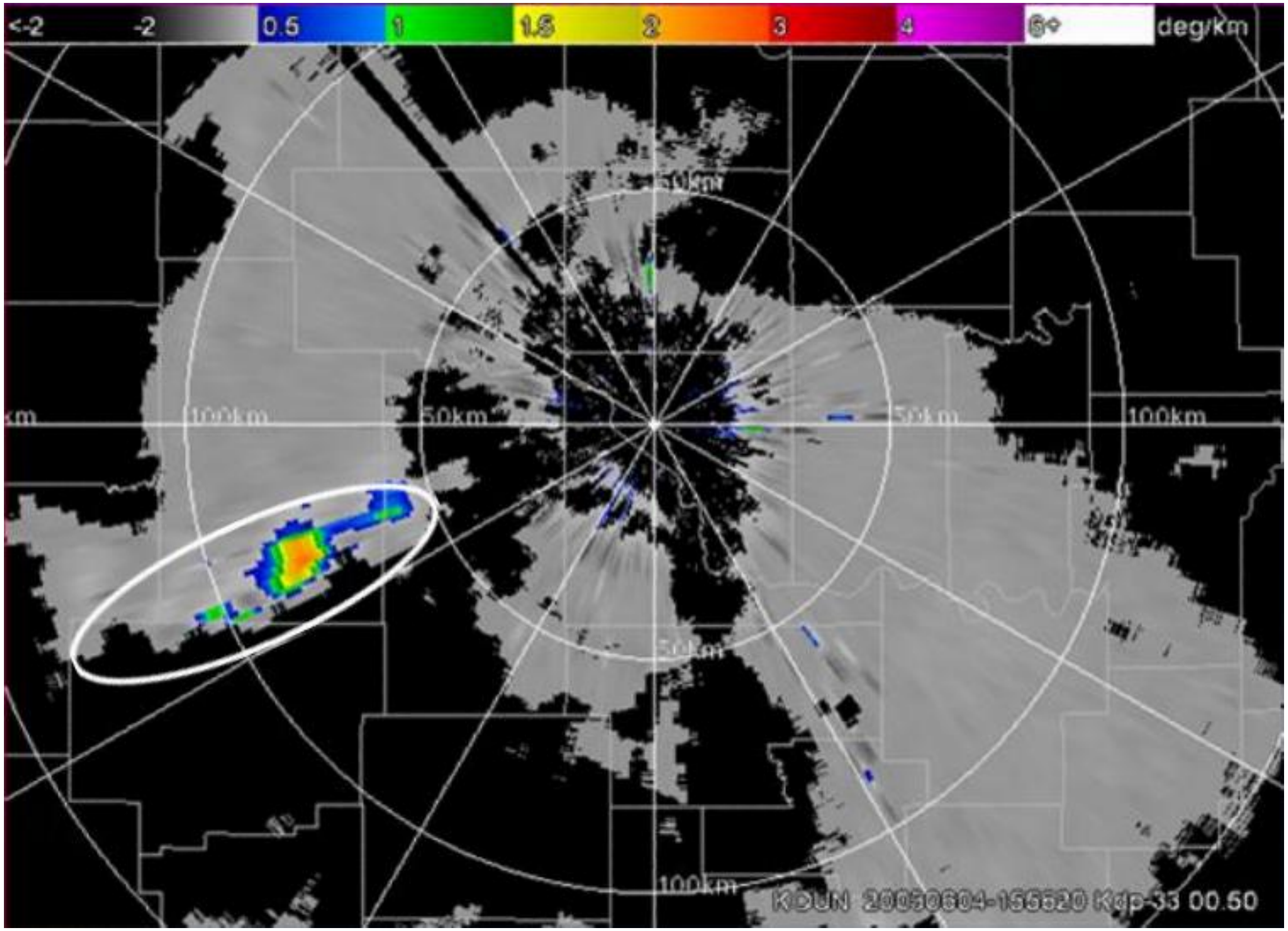


Phase shift larger at horizontal polarization than vertical
No Phase shift
No additional Differential Phase Shift, but beam still returns with ϕ_{dp}=10°
ϕ_{dp}=0°
ϕ_{dp}=10°



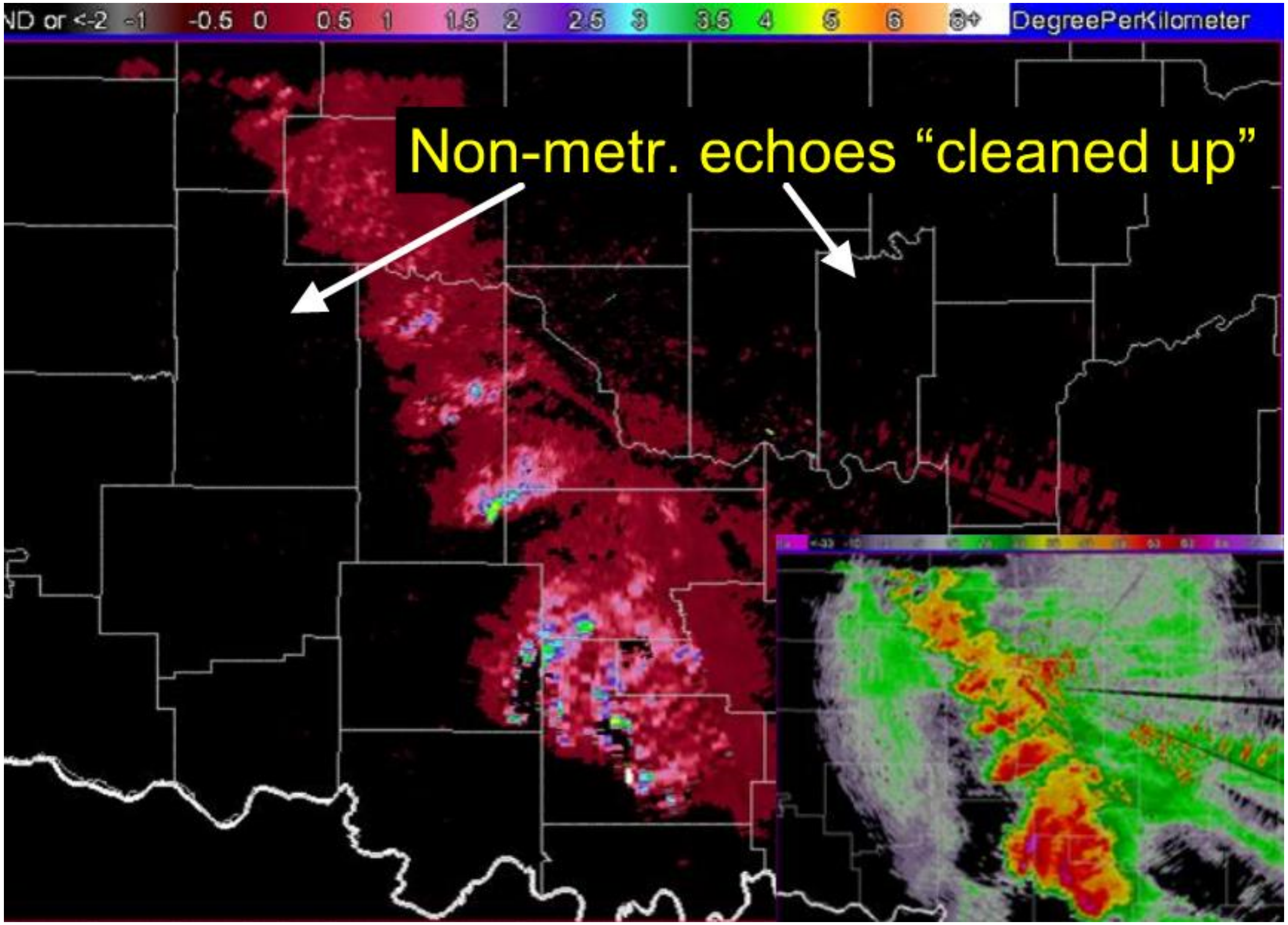
Increase amount of rain:
Phase shift much larger at horizontal polarization than vertical
No additional Differential Phase Shift, but beam still returns with ϕ_{dp}=25°
ϕ_{dp}=0°
ϕ_{dp}=25°

Specific Differential Phase:



Gradient areas of changing phase = greatest drop concentrations

KDP Example:


ND or <-2 -1 -0.5 0 0.5 1 1.5 2 2.5 3 3.5 4 5 6 8+ DegreePerKilometer
Non-metr. echoes "cleaned up"

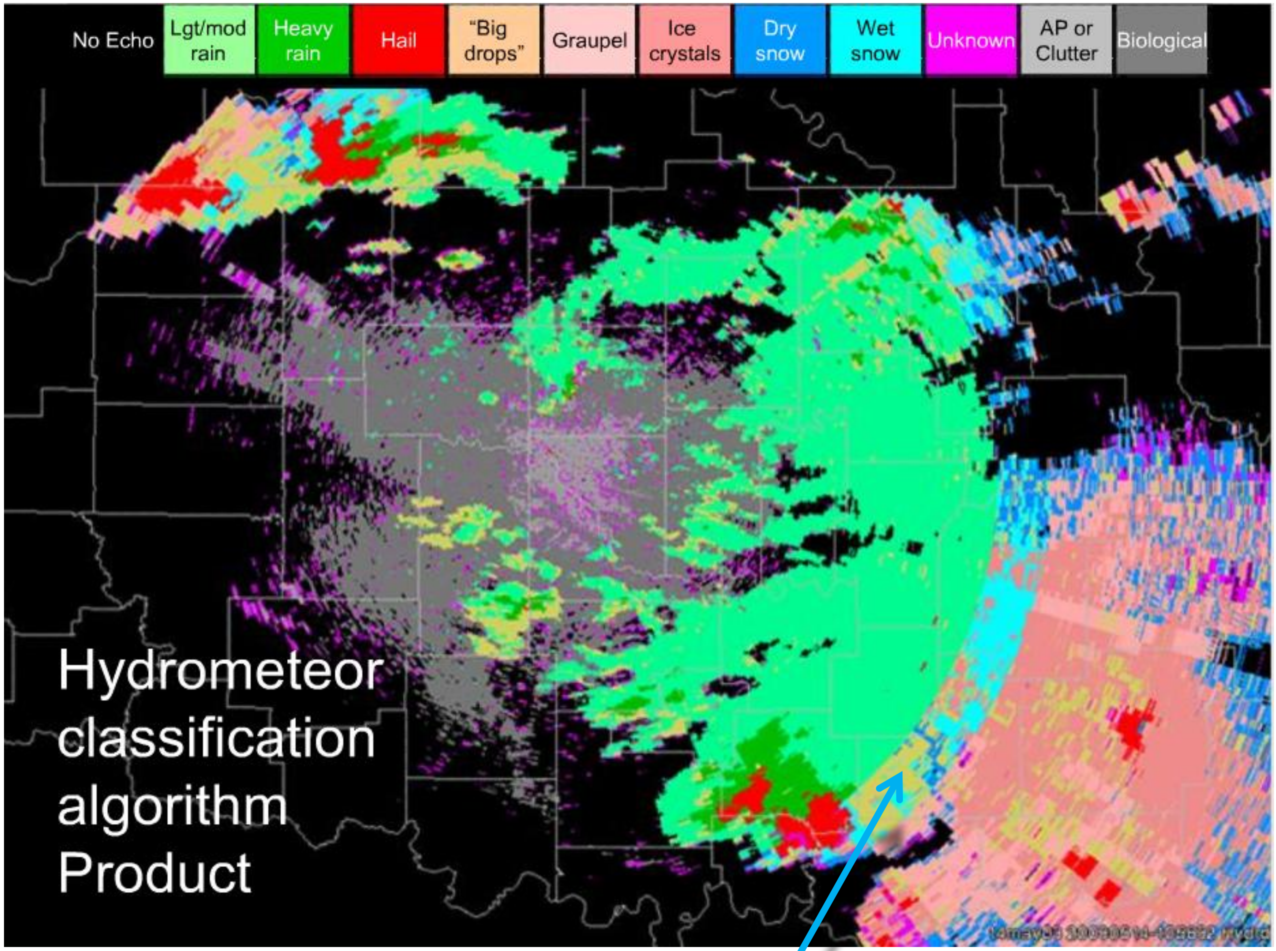
KDP Summary and Limitations:

- Excellent for rainfall estimation
- Strongly depends upon range length to integrate over
- Field can be noisy over shorter integration lengths
- Less effective at long ranges, and does not account for precipitation where CC is <0.87 (hail cores)

Potential Derived Products:

- Melting Layer Detection Algorithm (MLDA) – uses ZDR/CC to differentiate melting layer from regions of sub/above freezing layers
- Hydrometeor Classification Algorithm – assigns hydrometeor classification to each range bin (11 types). Uses base output, MLDA output and "fuzzy logic"
- Quantitative Precipitation Estimation (QPE) – including 8-bit instantaneous intensity

Example: HCA Output



Melting Zone

Summary

- Dual-Polarization will arrive at KLOT 03/2011
- New base products – ZDR, CC, "KDP"
- Improved precipitation estimates, identification of freezing/frozen/liquid precipitation types, location of hail cores, updrafts, etc.
- Identification of non-meteorological returns, and better filtering from processed data